

Article

Effect of Temperature on the Corrosion Resistance of Ni5Al Coating Deposited by Electric Arc in 3.5% NaCl Solution

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Abstract: The electrochemical behavior of the Ni5Al coating deposited by an electric arc was evaluated. Its behavior was evaluated in a saline solution as a function of temperature (20 °C, 40 °C, and 60 °C). The variation as a function of time of the Ni5Al coating's values of open circuit potential, linear polarization resistance, and the evolution of its electrochemical impedance spectra were analyzed. With this deposition technique, the rapid formation of thick coatings is achieved, which reduces the presence of interconnected porosity. Even though the microstructural characteristics showed the presence of trapped oxides, the electrochemical measurements carried out showed excellent corrosion resistance of the coating. The coating quickly develops a passive layer that allows it to rapidly reach thermodynamic equilibrium with the corrosive medium.

Keywords: Ni5Al coatings; corrosion; passive layer; RPL; EIS; electrochemical corrosion



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1. Introduction

In aqueous media, the degradation of materials and alloys occurs through electrochemical processes that involve the oxidation of one species and the reduction of another, that is, an electron transfer process. This degradation process is widely known as corrosion, and it is one of the main problems that cause significant economic losses in different industrial processes. [1–6]. The corrosive nature of an electrolyte depends on the dissolved species it contains as well as environmental conditions such as temperature. These degradation processes contribute to the deterioration of material properties and their premature failures [7–9].

In order to counteract these thermodynamically spontaneous processes, corrosion prevention and control techniques have been implemented. Some of them can be corrosion inhibitors, cathodic protection, selection of materials, and surface modification through the application of coatings, among others. With the implementation of these actions, it has been possible to increase the useful life of the materials. However, the choice of prevention techniques depends on the location and environmental conditions of the surface to be protected. In particular, the use of metallic coatings is a way of modifying the chemical composition of a substrate with poor resistance to corrosion. In this way, a coated system achieves high chemical stability in a corrosive environment. Coatings applied by thermal spray can be a technical solution for corrosion problems at both low and high temperatures [2,9–18].

Through thermal spraying, it is possible to modify the chemical composition of the surface of a substrate. The deposited layers can be made of both metallic and non-metallic materials (ceramics and polymers). For it, materials in powder or wire form are heated to or near their melting point and projected at high velocity onto the substrate to produce

satisfactory bond strength without changing the metallurgical characteristics of the base metal [9]. These characteristics make thermal spraying one of the most versatile tools for protecting materials [14].

The protective properties of a coating are also dependent on the thermal spray method used for its deposition (plasma spray, electric arc spray, cold spray, flame spray, high velocity oxy-fuel spray, etc.), since it influences the coating's microstructural characteristics [14,15,17]. To guarantee good corrosion protection, in addition to excellent chemical stability, it is necessary to minimize defects such as interconnected porosity. This reduces the risk of diffusion of the electrolyte to the substrate.

Due to its high speeds of spraying, the electric arc thermal projection technique is a good alternative to carry out the surface modification of a substrate to increase its resistance to corrosion, recover dimensions, increase its resistance to wear, etc., without affecting the microstructural properties of the substrate [16].

Regarding corrosion resistance, various studies have shown that Ni-based alloys deposited as protective coatings show greater chemical stability than those based on Fe [2,9–21]. Ni5Al coatings are generally used as an anchor layer for the deposition of a top coating with low bond strength towards the substrate; however, according to their chemical composition, they may also present excellent corrosion resistance in certain corrosive environments. Therefore, the objective of this study is to evaluate the electrochemical performance of the Ni5Al coating deposited by an electric arc. Its evaluation was carried out in a NaCl solution (3.5 wt.%) at temperatures of 20 °C, 40 °C, and 60 °C, and its electrochemical performance was obtained through measurements of open circuit potential, linear polarization resistance, and electrochemical impedance.

2. Materials and Methods

Ni5Al coating. The coatings were generated with a Ni5Al alloy in the form of a wire, which was deposited by the electric arc spray technique on 304 stainless steel plates. Prior to the deposition of the coating, the stainless-steel plates were cleaned with acetone, and their surface was shotblasted with alumina particles in accordance with the recommended practice of NACE No. 1/SSPC-SP 5. After surface preparation, the metal plates were cleaned again with dry air and acetone, and the coatings were deposited in that condition. A copper wire was soldered to each coated plate on the uncoated rear face, and in that condition, they were encapsulated in epoxy resin. The surface of the coatings was roughed with abrasive paper from grade 120 to grade 600, and in that surface condition, the corrosion tests were carried out.

Electrochemical tests. As corrosive medium, a 3.5% NaCl solution (% by weight) was used, and the corrosion tests were carried out at 20 °C, 40 °C, and 60 °C for 24 h. An electrochemical cell with three electrodes was used, where the working electrode was Ni5Al coatings encapsulated in epoxy resin, a saturated calomel electrode (SHE) was used as a reference electrode, and a graphite rod was used as an auxiliary electrode. Open circuit potential (OCP), linear polarization resistance (LPR), and electrochemical impedance spectroscopy (EIS) measurements were performed. OCP values were recorded as a function of time, and LPR measurements were performed by polarizing the working electrode ± 10 mV with respect to the corrosion potential at a sweep rate of 10 mV/min. EIS measurements were evaluated under open circuit conditions by applying a sinusoidal AC signal with an amplitude of ± 10 mV in the frequency range of 100 kHz to 0.01 Hz.

3. Results and Discussion

3.1. Structural Aspects of the Coating

Figure 1 shows the cross-sectional appearance of the Ni5Al coating. The morphological aspects observed are consistent with the typical characteristics associated with coatings deposited by the thermal spray technique, that is, a heterogeneous structure, the formation of the coating by the overlapping of layers, segregation of phases, the presence of trapped oxides, and porosity [9–18]. A great advantage of the electric arc coating deposition

technique is the rapid formation of thick coatings. The thickness of a coating is an important parameter because the greater the thickness, the lower the probability of interconnected porosity [9,15]. According to the measurements made, the average thickness of the coating after the grinding process was $1\text{ mm} \pm 50\text{ }\mu\text{m}$.

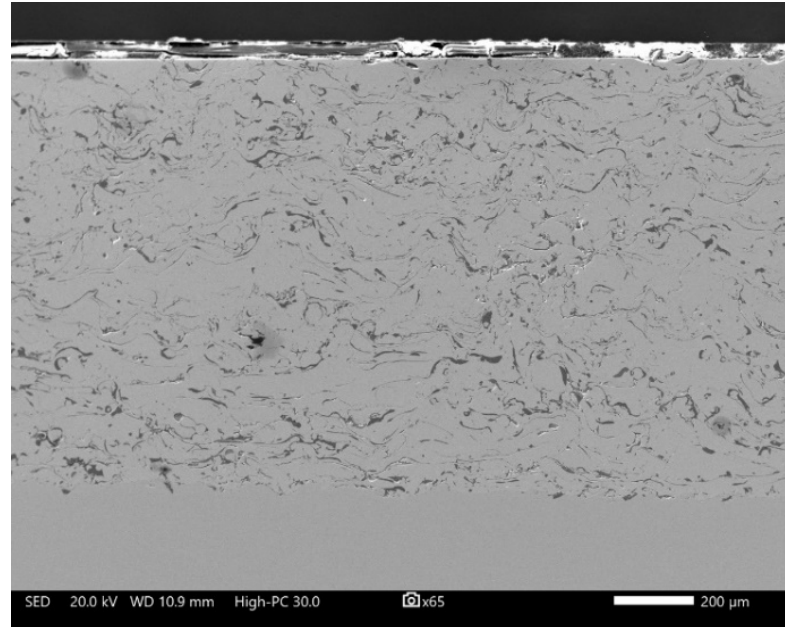


Figure 1. Cross-sectional aspect of the Ni5Al coatings.

Figure 2 shows an approach to the cross section of the Ni5Al coating and its element mapping. It shows details of the structure of the coating formed by the impact and deformation of the drops of liquid metal and the presence of trapped oxides. The dark phases correspond to trapped aluminum oxides, and the clear gray phases to the Ni5Al alloy [15,17].

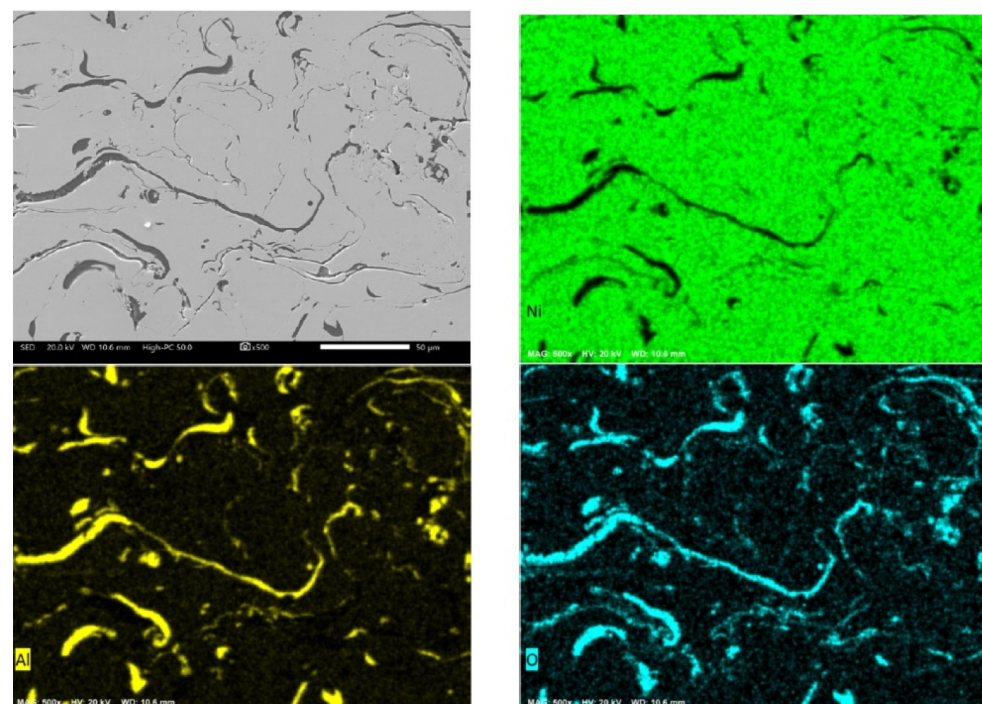


Figure 2. Details and mapping of elements to the cross section of the Ni5Al coatings.

3.2. Open Circuit Potential Curves

Figure 3 shows the evolution of the open circuit potential as a function of time for the Ni5Al coating immersed in saline solution at the different test temperatures. The observed trend indicates that as the temperature increases, the coating tends to show a more active behavior.

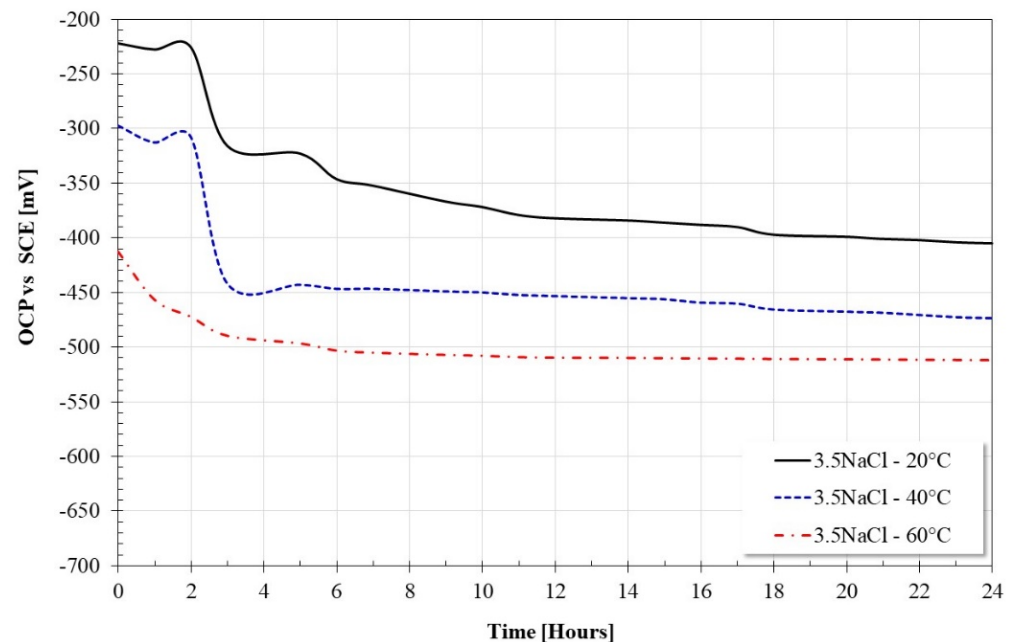


Figure 3. OCP values versus time for the Ni5Al coating.

Even though the grinding process reduced the heterogeneity of the surface and with it the presence of active sites, it is observed that at 20 °C and 40 °C, the coating showed a stable behavior in the first two hours of immersion, and subsequently an abrupt drop in potential values was observed. After the abrupt drop in potential values, a steady decline was observed until the end of the test. The magnitude of the potential drop was lower at 60 °C, as was its variation after 5–6 h of immersion, possibly due to the rapid formation of a passive layer on the coating surface.

The trend of the open circuit potential values provides a clear trend of the active-passive behavior of the surface under study. In this case, the greatest active behavior was observed in the first hours of immersion. After that, the fluctuations were minimal or insignificant, which suggests the establishment or development of a protective layer on the coating surface.

It has been suggested that the observed behavior may be associated both with the presence of surface defects (pores and oxides) [10,22–24] and with the absence of a passive layer [10,13,25]. Both situations activate the metallic dissolution process since they allow the infiltration of the electrolyte through the superficial defects as well as the direct contact of the metallic surface with the aggressive environment due to the absence of a protective layer [10,12,13,22,23,25] or the presence of superficial defects such as porosity, voids, or oxides trapped [22–24].

3.3. Linear Polarization Resistance Curves

Figure 4 shows the evolution of the resistance values to linear polarization as a function of time for the Ni5Al coating immersed in saline solution at the different test temperatures. The figure shows a clear effect of temperature on the corrosion rate; that is, the increase in temperature reduces the resistance to polarization of the coating.

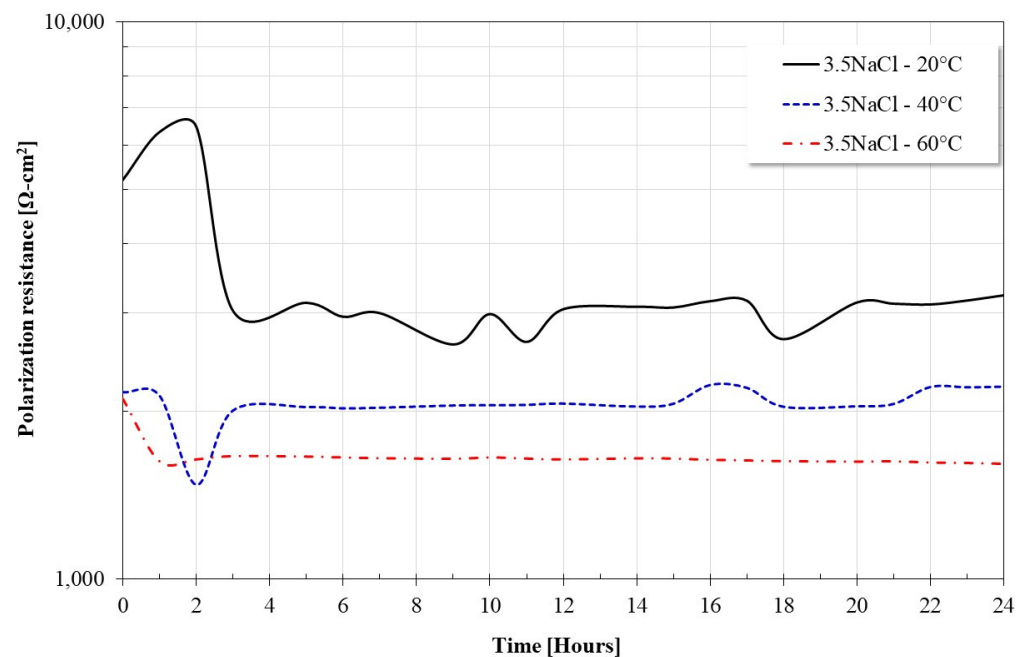
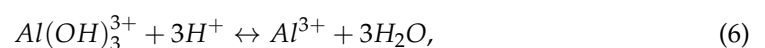
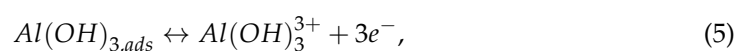
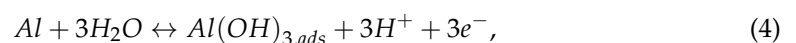
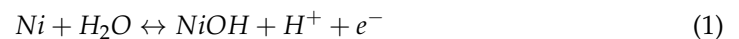


Figure 4. Change in Rp values over time for the Ni5Al coating.

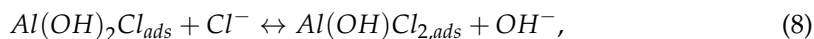
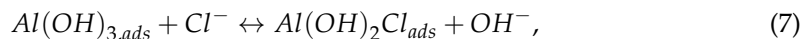
At 20 °C, at the beginning of the test, in the first three hours of immersion, an increase in the Rp values was observed, followed immediately by a sharp drop, and after that, a quasi-stationary behavior where the Rp values oscillated around 3000 ohm-cm². A similar behavior was observed at 40 °C, with a slight increase in the Rp values followed by a decrease and a subsequent increase, and after three hours of immersion, a quasi-stable behavior with Rp values around 2000 ohm-cm² during the rest of the test. On the other hand, at 60 °C, only a decrease in Rp values was observed during the first hour of immersion, followed by a quasi-stable behavior with Rp values around 1600 ohm-cm² during the rest of the test. The evolution of the Rp values is consistent with that of the OCP values shown in Figure 3. Despite the lower corrosion resistance observed at 60 °C, at this temperature the coating showed the most stable behavior, which may be due to the rapid development of a protective layer on the surface of the coating.

The evolution of both the OCP and Rp values is due to the anodic and cathodic processes that occur on the surface of the coating. In general, it can be said that the anodic dissolution is due to the occurrence of the following reactions [10,26–30]:



It has been reported that the formation and accumulation of hydroxides, as well as oxyhydroxides, can retard the metal dissolution process because their presence limits the diffusion of aggressive species towards the metal surface [10,31].

However, in the presence of chloride ions, the following side reactions are also possible [10,32,33]:



Similar reactions are possible for Ni hydroxides. Since these reactions occur on the metal surface, they affect the adhesion of the layer of protective corrosion products, thereby enhancing the corrosion process [10].

3.4. Electrochemical Impedance Spectroscopy

Figure 5 shows the evolution of the electrochemical impedance spectra as a function of time for the Ni5Al coating immersed in the saline solution at 20 °C. The Nyquist diagram shows the presence of at least two overlapping depressed capacitive semicircles, whose diameters vary as a function of immersion time. The Bode diagram in its impedance modulus format, $|Z|$, in the high frequency region (>1000 Hz) shows the presence of the high frequency plateau, and in the intermediate and low frequency regions, the presence of several slopes in the linear relationship ($\log f$ - $\log |Z|$). Each observed slope is associated with a capacitive semicircle observed in the Nyquist diagram. The presence of the low frequency plateau is not observed, which suggests that the impedance modulus is greater than the last recorded value (>3 kHz). From the Bode plot in its phase angle ($^{\circ}$) format, there is a clear presence of three time constants, each associated with each slope of the linear relationship, $\log f$ - $\log |Z|$, as well as with each capacitive semicircle present in the Nyquist diagram. The first time constant is observed between 10 and 100 Hz, the second around 1 Hz, and the third at frequencies less than 0.1 Hz. The first time constant shows the highest value of the maximum phase angle and may be associated with the capacitive response of the coating surface. It is observed that at the beginning of the test, the maximum phase angle decreased until 6 h of immersion ($57^{\circ} \rightarrow 50^{\circ}$) and subsequently showed a constant increase until reaching a value of 60° at the end of the test. The other time constants showed a decreasing behavior in their maximum value of phase angle, and these may be associated either with processes of adsorption or diffusion of species due to the presence of films of adsorbed metal hydroxides according to the corrosion mechanism indicated in the previous section.

Figure 6 shows the evolution of the electrochemical impedance spectra as a function of time at 40 °C. From the Nyquist diagram, it is possible to observe the presence of several depressed capacitive semicircles, which apparently overlap. The Bode plot, in its impedance modulus format, $|Z|$, in the high frequency region (>1000 Hz) also shows the presence of the high frequency plateau, and again in the intermediate and low frequency regions, several slopes of the linear relationship ($\log f$ - $\log |Z|$) are observed. The presence of the low frequency plateau is not observed, which suggests that the impedance modulus is greater than the last recorded value (>2.1 kHz). From the Bode plot in its phase angle ($^{\circ}$) format, it is also possible to observe the presence of three time constants. As observed at 20 °C, the first is located between 10 and 100 Hz, the second around 1 Hz, and the third at frequencies less than 0.1 Hz. The meaning of the time constants can be the same as that described below. Unlike what was observed at 20 °C, in this case, for the first time constant, it is observed that the maximum of the phase angle increased constantly throughout the test ($46^{\circ} \rightarrow 57^{\circ}$). The other time constants showed a behavior similar to that observed at 20 °C.

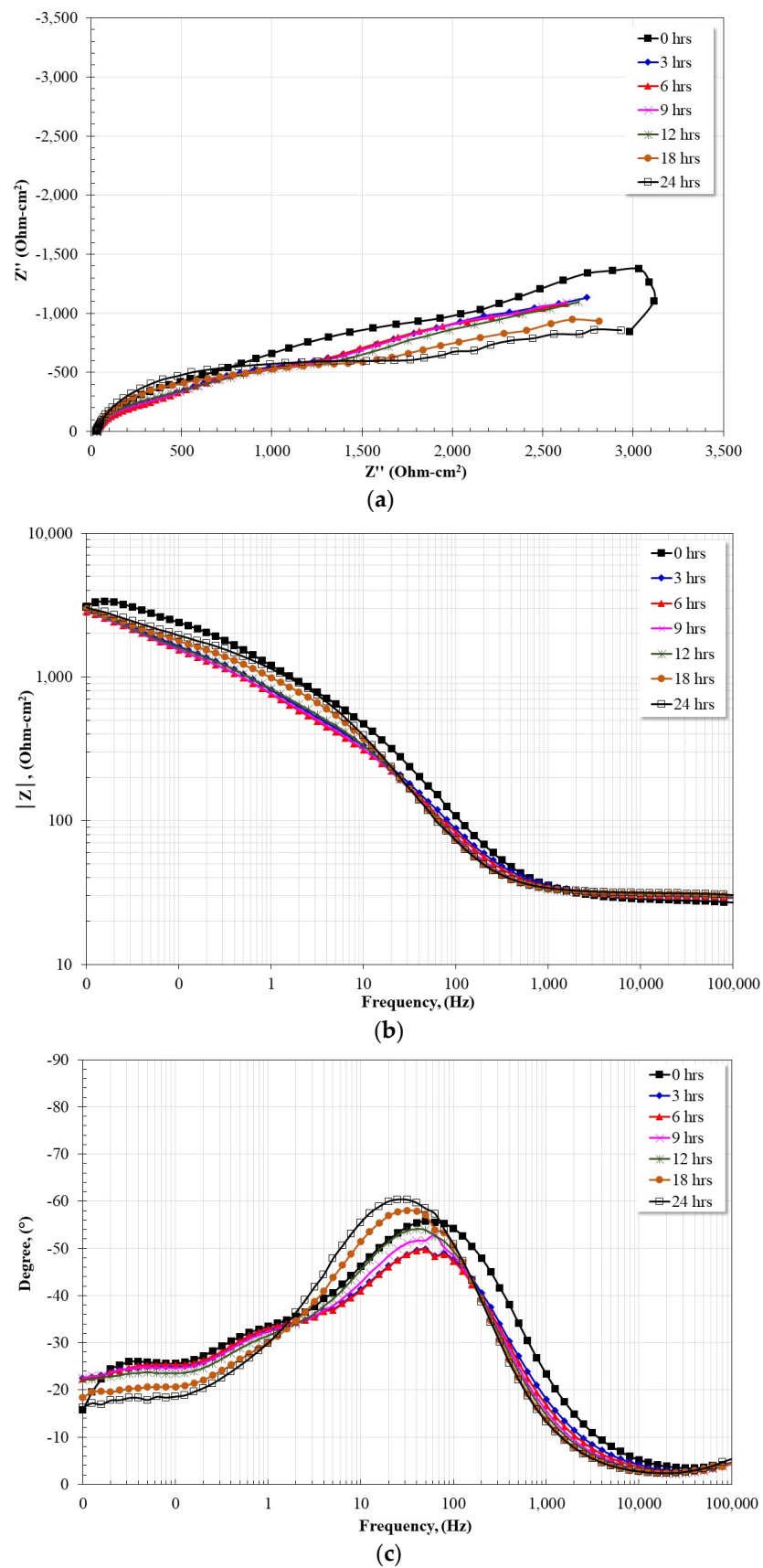


Figure 5. Evolution of the Nyquist and Bode diagrams for the Ni5Al coating immersed in saline solution at 20 °C. (a) is Nyquist diagram; (b) is Bode plot, impedance modulus; (c) is Bode plot, phase angle.

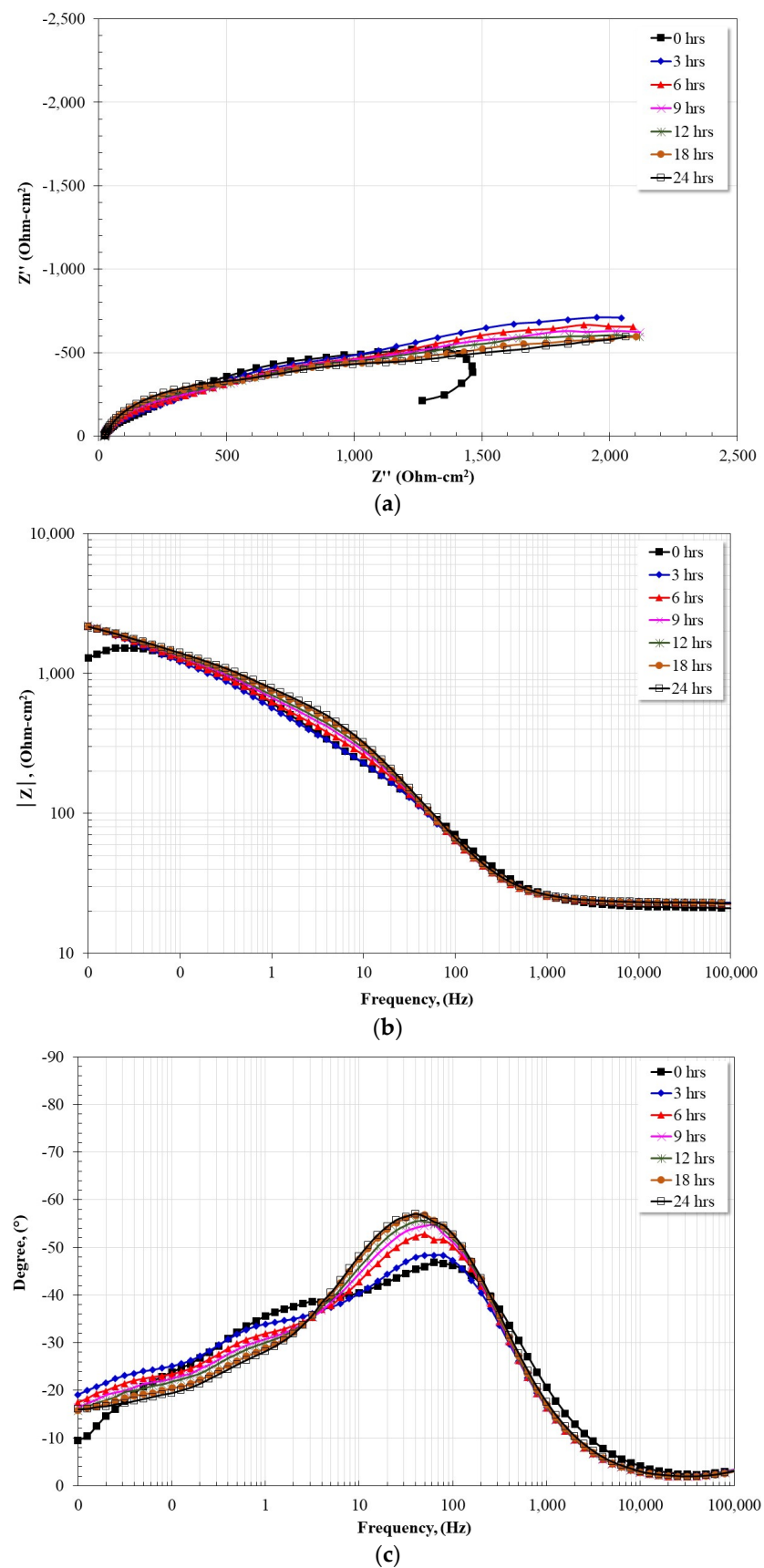


Figure 6. Evolution of the Nyquist and Bode diagrams for the Ni5Al coating immersed in saline solution at 40 °C. (a) is Nyquist diagram; (b) is Bode plot, impedance modulus; (c) is Bode plot, phase angle.

Figure 7 shows the evolution of the electrochemical impedance spectra as a function of time at 60 °C. The Nyquist diagram suggests the apparent presence of two depressed capacitive semicircles, which apparently overlap. Their diameters show little variation with immersion time. The Bode plot, in its impedance modulus format, $|Z|$, shows characteristics similar to those described at lower temperatures. That is, in the high frequency region (>1000 Hz), the presence of the high frequency plateau is observed, and in the intermediate and low frequency regions, several slopes are observed in the linear relationship ($\log f - \log |Z|$). Once again, the presence of the low-frequency plateau is not observed, indicating that the impedance modulus is greater than the last recorded value (>1.2 kHz). The Bode plot in its phase angle ($^\circ$) format also shows the presence of three time constants in the same frequency regions noted above. The maximum of the phase angle of the first time constant tends to increase with the immersion time ($43^\circ \rightarrow 50^\circ$), and that of the second and third time constants showed the opposite behavior.

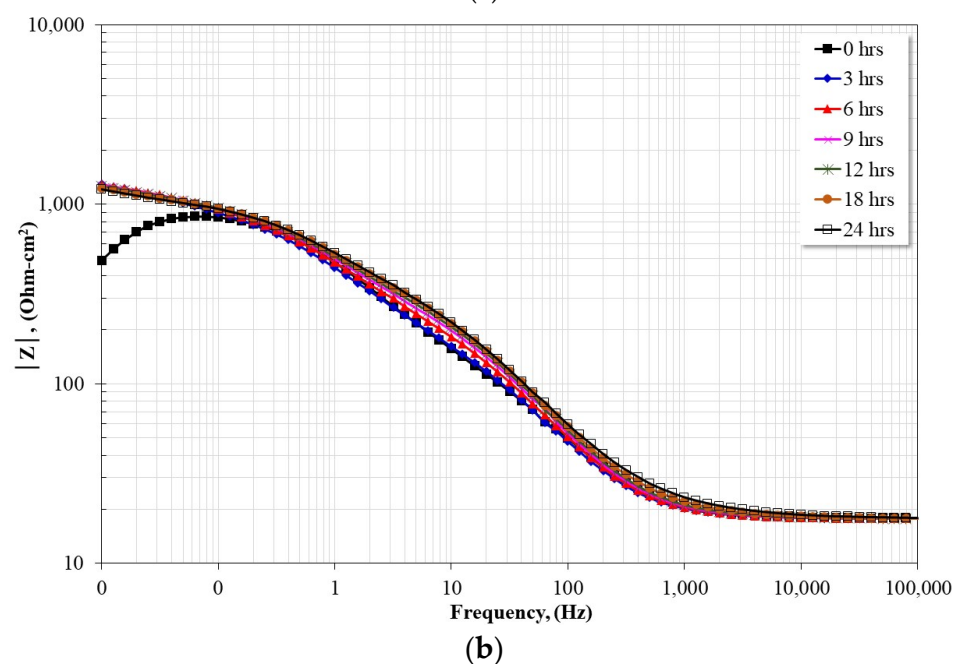
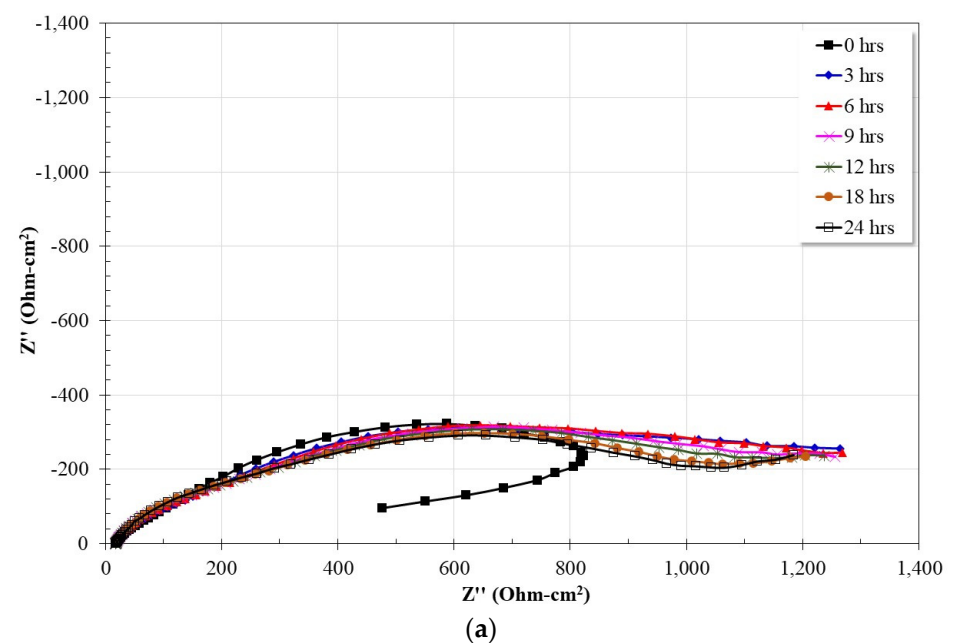


Figure 7. Cont.

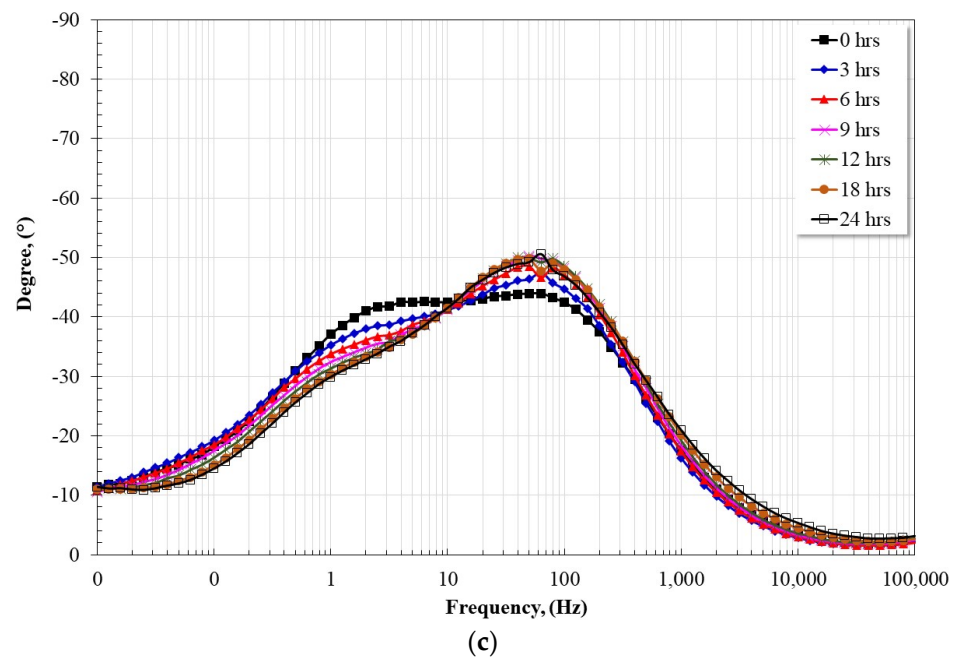


Figure 7. Evolution of the Nyquist and Bode diagrams for the Ni5Al coating immersed in saline solution at 60 °C. (a) is Nyquist diagram; (b) is Bode plot, impedance modulus; (c) is Bode plot, phase angle.

It is interesting to observe that at the end of the test (24 h), the maximum of the phase angle of the first time constant tended to decrease with the increase in temperature ($61^\circ \rightarrow 57^\circ \rightarrow 50^\circ$) and also experienced a displacement at higher frequencies (25 Hz $\rightarrow$ 40 Hz $\rightarrow$ 50 Hz). It has been reported that the decrease in the phase angle is due to the decrease in both the corrosion resistance and the capacitive properties of the passive film formed, in addition to the compactness of the passive film [34–37], and that the displacement of the phase angle at higher frequencies has been associated with an increase in the thickness of the protective layer [37]. On the other hand, at the end of the test, the second time constant did not show significant changes in either the maximum phase angle or its position, and the third time constant tended to decrease with increasing temperature. This may be due to the permanent presence of an adsorbed film of metal hydroxides that is formed during the metal dissolution process and the fact that, with an increase in temperature, the diffusion rate of aggressive species increases [10].

Based on the above, the impedance spectra were analyzed using the equivalent circuit shown in Figure 8. The first time constant is associated with the adsorption process of the metal hydroxide film and is represented by the constant phase element (CPE_{ads}) in parallel with the resistance of the adsorption process (R_{ads}). The second time constant is associated with the presence of a layer of adsorbed metal hydroxides and is represented by the constant phase element (CPE_f) in parallel with the resistance of the adsorbed film (R_f). The third time constant is represented by the constant phase element (CPE_{dl}) in parallel with the charge transfer resistance (R_{ct}).

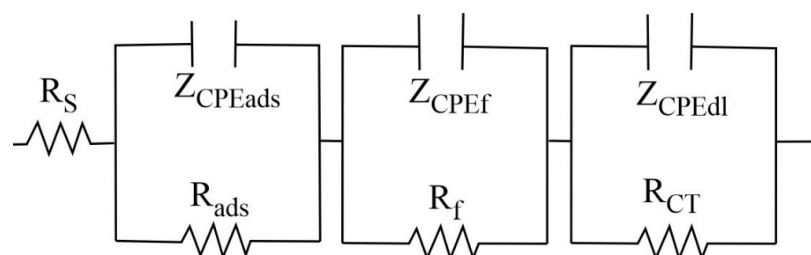


Figure 8. Equivalent circuit used to fit the impedance spectra.

The impedance of the CPE is defined by the expression [38]:

$$Z_{CPE} = \left(\frac{1}{Y_0} \right) (j\omega)^{-n}, \quad (10)$$

CPE is commonly used instead of capacitance when the capacitive semicircles are depressed, and this is mainly attributed to surface imperfections. In this case, Y_0 , also known as admittance, is a constant whose magnitude is proportional to the active area in contact with the electrolyte, $j = \sqrt{-1}$, ω = angular frequency (rad/s), and $n = \alpha/(\pi/2)$, where α is the phase angle of the CPE [39].

Tables 1–3 show the value and evolution of the electrochemical parameters as a function of time.

Table 1. Electrochemical parameters of the electrochemical impedance spectroscopy (EIS) at 20 °C.

Time (h)	R_{CT} ($\Omega \cdot \text{cm}^2$)	$Y_{o_{dl}}$ ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_{dl}	R_f ($\Omega \cdot \text{cm}^2$)	Y_{o_f} ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_f	R_{ads} ($\Omega \cdot \text{cm}^2$)	Y_{ads} ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_{ads}
0	5230	3.4271×10^{-3}	0.62	1185	3.4707×10^{-4}	0.7	79.2	6.8921×10^{-5}	0.86
3	4787	1.6161×10^{-3}	0.58	820.3	4.5659×10^{-4}	0.75	236.7	8.7879×10^{-5}	0.87
6	4197	1.7331×10^{-3}	0.6	783.9	4.8316×10^{-4}	0.76	226.9	8.9884×10^{-5}	0.87
9	3944	1.9496×10^{-3}	0.64	827.5	4.5329×10^{-4}	0.76	252.9	8.402×10^{-5}	0.89
12	3743	2.112×10^{-3}	0.65	863.8	4.3681×10^{-4}	0.78	321.8	8.2458×10^{-5}	0.89
18	3194	2.1309×10^{-3}	0.65	867.1	4.107×10^{-4}	0.81	492.4	7.8769×10^{-5}	0.89
24	2939	2.0608×10^{-3}	0.64	872.8	3.728×10^{-4}	0.84	635.5	7.6915×10^{-5}	0.9

Table 2. Electrochemical parameters of the electrochemical impedance spectroscopy (EIS) at 40 °C.

Time (h)	R_{CT} ($\Omega \cdot \text{cm}^2$)	$Y_{o_{dl}}$ ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_{dl}	R_f ($\Omega \cdot \text{cm}^2$)	Y_{o_f} ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_f	R_{ads} ($\Omega \cdot \text{cm}^2$)	Y_{ads} ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_{ads}
0	2230	1.1607×10^{-3}	0.66	481	5.4595×10^{-4}	0.75	108.1	1.1827×10^{-4}	0.85
3	2174	2.791×10^{-3}	0.69	749	5.7519×10^{-5}	0.74	166.5	1.1339×10^{-4}	0.86
6	1991	2.7736×10^{-3}	0.7	725.9	5.5912×10^{-4}	0.77	242.6	1.0027×10^{-4}	0.87
9	1878	2.8209×10^{-3}	0.7	722	5.6178×10^{-4}	0.78	294.9	9.553×10^{-5}	0.87
12	1804	2.8838×10^{-3}	0.7	716.3	5.6666×10^{-5}	0.79	338.7	9.3554×10^{-5}	0.86
18	1788	3.1535×10^{-3}	0.69	722.9	5.8251×10^{-4}	0.79	404.4	9.1253×10^{-5}	0.87
24	1790	3.669×10^{-3}	0.68	756.8	6.2464×10^{-4}	0.78	459.6	9.1898×10^{-5}	0.86

Analysis of $Y_{o_{dl}}$ values shows that they increase with increasing temperature. At 20 °C, these show an increase in the first three hours of immersion and then tend to decrease slightly as a function of time. However, at 40 °C and 60 °C, these tend to increase as a function of time. This suggests that the increase in temperature reduces the corrosion resistance through an increase in the active reaction surface.

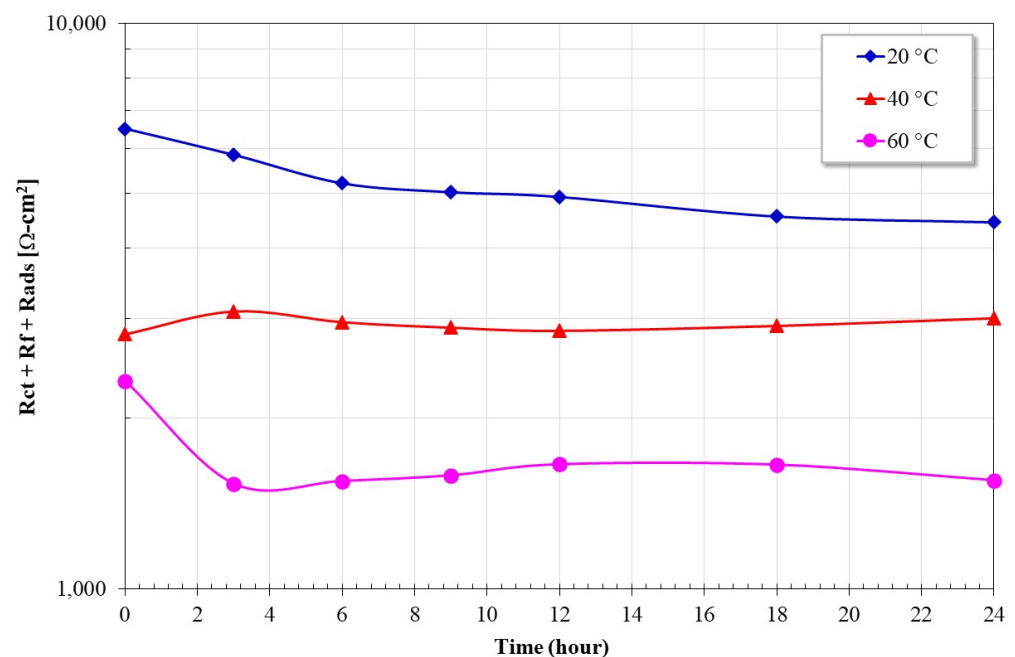
This is in accordance with the trend observed in the n_{dl} values. At 20 °C, a decrease is observed in the first three hours of immersion, followed by an increase that remains practically constant after 9 h. However, at 40 °C and 60 °C, the general trend is that n_{dl} values tend to decrease as a function of time. Since Y_o is associated with the effective reaction area and n with the irregularity and/or surface roughness, this indicates the presence of a parallel process that is causing the observed changes (see Section 3.5 SEM analysis).

Table 3. Electrochemical parameters of the electrochemical impedance spectroscopy (EIS) at 60 °C.

Time (h)	R_{CT} ($\Omega \cdot \text{cm}^2$)	$Y_{o_{dl}}$ ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_{dl}	R_f ($\Omega \cdot \text{cm}^2$)	Y_{o_f} ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_f	R_{ads} ($\Omega \cdot \text{cm}^2$)	Y_{ads} ($\Omega^{-1} \cdot \text{cm}^{-2} \cdot \text{s}^n$)	n_{ads}
0	1354	6.2125×10^{-3}	0.7	931.5	4.8139×10^{-4}	0.7	44.89	2.0732×10^{-4}	0.87
3	702.6	6.5276×10^{-3}	0.69	738.1	5.9689×10^{-4}	0.74	91.34	1.8407×10^{-4}	0.85
6	667.1	6.8598×10^{-3}	0.68	753.6	5.961×10^{-4}	0.74	127.8	1.6344×10^{-4}	0.84
9	641.9	9.1178×10^{-3}	0.67	792.6	5.901×10^{-4}	0.73	150.2	1.4968×10^{-4}	0.84
12	674.2	1.2367×10^{-2}	0.66	812.4	5.9086×10^{-4}	0.73	171.1	5.9086×10^{-4}	0.73
18	693	1.1406×10^{-2}	0.53	778	5.9459×10^{-4}	0.73	183.9	1.6432×10^{-4}	0.82
24	649	1.0918×10^{-2}	0.43	720.2	5.9675×10^{-3}	0.74	184.4	1.7161×10^{-4}	0.82

On the other hand, since the films formed on the surface act as insulators between the metallic surface and the electrolyte, their Y_{o_f} values must be less than those of the metallic surface, and their n_f values must tend towards unity. The analysis of both values shows that indeed, the presence of oxy-hydroxide films tends to decrease the active area and reduce the surface roughness. This is because even when this active area exists, the film formed hides it. It has been reported that this is associated with film thickness and/or low electrical permittivity [40].

Considering that the sum of the resistances of the time constants is similar to the R_p values, Figure 9 shows these results. When comparing the results obtained with the R_p values (Figure 4), it is observed that the trend of the values is similar; however, the values at 20 °C and 40 °C are higher than those corresponding with the R_p measurements. This is consistent with the EIS measurements since in none of the cases was it possible to define the formation of the low-frequency plateau, and the adjustment of the data with the equivalent circuit allows us to predict the value of the impedance module where this would occur. Nevertheless, the electrochemical behavior is much better than that reported in other studies that use more complex deposition techniques, such as thermal plasma spraying [41].

**Figure 9.** Graphical representation of the sum of $R_{ct} + R_f + R_{ads}$.

3.5. SEM Analysis

Figure 10 shows the morphological aspects after the corrosion test of the Ni5Al coating in saline solution at the different test temperatures. Even though the surface of the coating was roughened to obtain a homogeneous surface, it is evident that the dark phases corresponding to the aluminum oxides that were trapped during the formation of the coating are observed on it. It is worth noting that it is still possible to see the marks of the surface preparation process, which suggests that despite the increase in temperature, the rate of corrosion experienced by the coating was negligible. The only visible signs of degradation are in the dark phases that correspond to the trapped aluminum oxides. This is understandable since these aluminum oxides do not correspond to the formation of protective films but to trapped oxides. It has been reported that even Al-based passive films are susceptible to failure in aqueous halide solutions [10,42,43]. The degradation of these phases caused an increase in the effective reaction area, which could have caused the variations in the Y_{oAl} and n_{Al} values discussed previously.

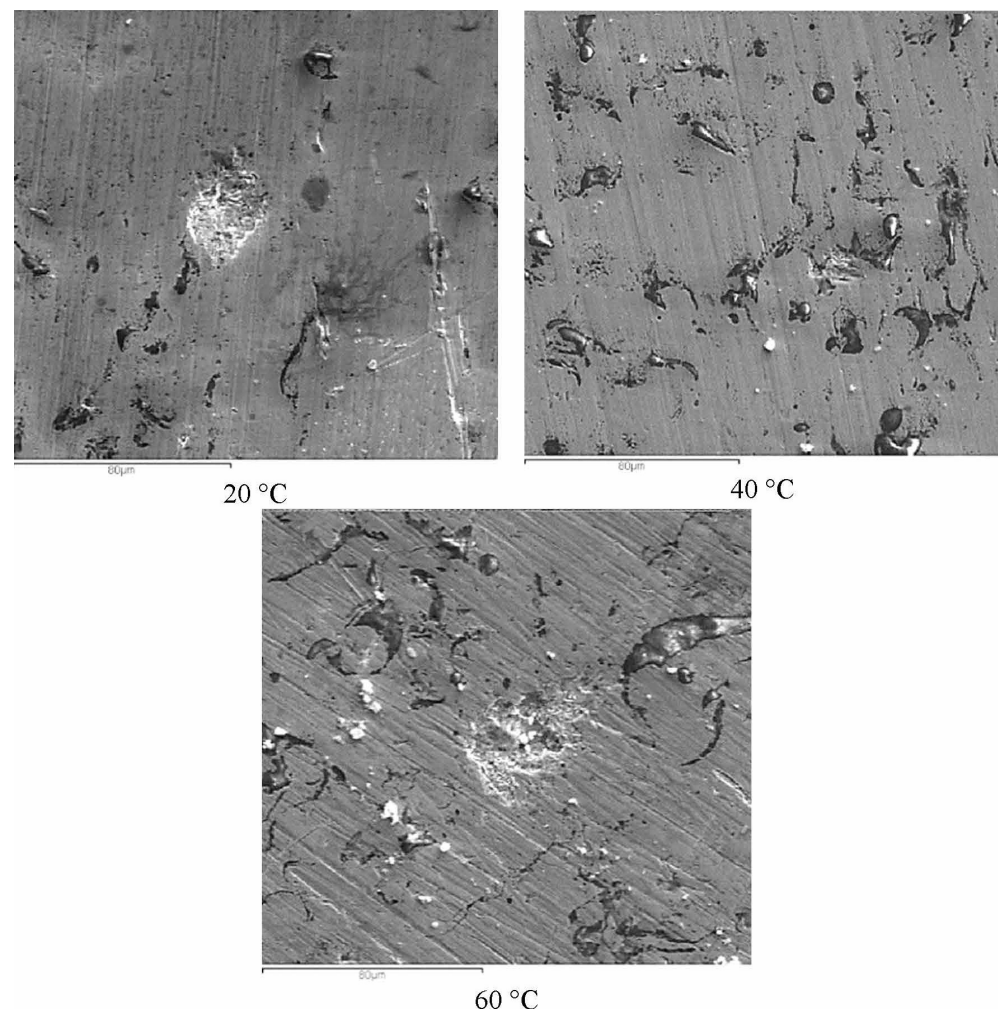


Figure 10. Surface morphology of the Ni5Al coating after exposure to the NaCl solution.

The results obtained suggest that the Ni5Al coatings deposited by the electric arc technique have a high resistance to corrosion in saline solutions at a wide range of temperatures. The OCP, R_p , and EIS measurements showed that the surface of the coating reaches thermodynamic equilibrium with its environment in a short time since quasi-stable values of potential, resistance to polarization, and impedance modulus are reached.

4. Conclusions

The electric arc thermal spray technique is a suitable process for the deposition of thick coatings. The OCP and Rp measurements indicated that the coating rapidly reaches its thermodynamic equilibrium with the corrosive medium due to the formation of a passive layer. The EIS measurements showed that the corrosion process can be represented by three time constants. The first one is the capacitive-resistive response of the metal surface, while the other two are relaxation processes due to the adsorption of metal hydroxides formed during the anodic process and the adsorption process of these species. The increase in temperature (as well as the immersion time) causes a decrease in the maximum phase angle ($61^\circ \rightarrow 57^\circ \rightarrow 50^\circ$) and its displacement towards the high frequency region (25 Hz $\rightarrow$ 40 Hz $\rightarrow$ 50 Hz). The relaxation process associated with the metal hydroxide layer (Ni and/or Al) does not undergo changes since it is an intermediate step of the anodic process, and that associated with the adsorption process decreases its influence with the increase in temperature, possibly due to the increase in the diffusion rate of the species.

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